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AN APPRAISAL OF FLYASH BASED MONOLITHIC PACKING FOR USE AT LINGAN COLLIERY, NOVA SCOTIA

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MICROMEDIA

AN APPRAISAL OF FLYASH BASED MONOLITHIC PACKING FOR USE AT LINGAN COLLIERY, NOVA SCOTIA

by

P. Cain*

ABSTRACT

'Flashpack' is a low cost monolithic pumped packing system based on flyash and ordinary portland cement. Both of these are available at low cost in Cape Breton. 'Flashpack' is therefore a practical and inexpensive alternative to 'Astrapack', the packing system recently introduced at Lingan Colliery and currently being imported from the U.K.

This report describes the 'Flashpack' system and its use at Parsonage Colliery in the U.K., which the author visited in November 1985. A programme for introducing the system to Lingan Colliery, based on observations made during the visit is proposed.

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ÉVALUATION DU REMBLAYAGE MONOLITHIQUE À BASE DE CENDRES VOLANTES POUR LA HOUILLÈRE LINGAN EN NOUVELLE-ÉCOSSE

par

P. Cain*

RÉSUMÉ

La méthode "Flashpack" est un système économique de remblayage monolithique par pompage à base de cendres volantes et de ciment Portland ordinaire. Ces deux matériaux sont disponibles à bas prix au Cap-Breton. Par conséquent, le système "Flashpack" est une méthode de rechange pratique et peu coûteuse au système de remblayage "Astrapack" adopté récemment à la houillère Lingan et que l'on importe présentement du Royaume-Uni (R.-U.).

Le présent rapport donne une brève description du système "Flashpack" et de l'emploi qu'on en fait à la houillère Parsonage (R.-U.) visitée en novembre 1985 par l'auteur. Suite aux observations faites au cours de cette visite, un programme visant à introduire le système à la houillère Lingan est proposé dans ce rapport.

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1. INTRODUCTION

Monolithic pumped packing (MPP) was introduced at Lingan Colliery, Nova Scotia in March 1985 to reduce air leakage across longwall wastes. The system now in use is 'Astrapack', manufactured and marketed by Pozzament U.K. Ltd. Since its initial use in the maingate of the 9E District, it has been successful in reducing air leakage and improving ventilation efficiency. Another 'Astrapack' system is planned for installation in the 10E District, due to commence operation in March 1986.

A major disadvantage of 'Astrapack', however, is its high cost; materials alone for each pack cost $1400*, of which $200 is attributable to transportation from Great Britain. Considerable effort has been applied to the evaluation of alternative MPP systems utilizing materials indigenous to Nova Scotia. One such material is 'Flashpack'.

'Flashpack' is an MPP system based on flyash and ordinary portland cement (OPC). When these two ingredients are mixed with water and a suitable accelerator, a quick setting mortar is formed. Both flyash and OPC are available from sources close to Lingan Colliery at relatively low cost.

The original design work on flyash/OPC mixes for use in mine packs was done by the National Coal Board (NCB) in Great Britain. The method is used at Parsonage Colliery, near Manchester, England, where it has been very successful in the prevention of spontaneous combustion and gateroad support at a depth of over 1000 m.

The success of 'Flashpack' at Parsonage Colliery prompted the Cape Breton Development Corporation (CBDC) to arrange a visit (Appendix A) to assess the applicability of the method to conditions prevailing at Lingan Colliery. The author participated in this visit at the request

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*All costs given in this report are given in $Canadian. The exchange rate used in converting U.K. costs is $2 = £1.

of CBDC. This report is a summary of observations made on the visit, leading to recommendations concerning the implementation of flyash/OPC packing at Lingan Colliery.

2. 'FLASHPACK' AT PARSONAGE COLLIERY

The following is a review of the 'Flashpack' system employed at Parsonage Colliery, U.K.

2.1 PRINCIPLES

'Flashpack' is an MPP system based on flyash and OPC. In operation two slurries are mixed, one of flyash, bentonite, an accelerator and water, the other of OPC and water. Bentonite is required to keep the flyash in suspension. The accelerator may be either aluminium sulphate or ferrous sulphate; the former produces a faster set, the latter is less expensive. Both grouts are pumped to the face end where they are mixed in a mixing gun and sprayed into the prepared packhole. The resulting mortar mix gels instantaneously, so the elaborate packhole preparation usually associated with MPP systems is not required. The resulting pack generates strength rapidly from 0.4 MN/m^2 (58 psi) after two hours to 8.2 MN/m^2 (1189 psi) after twenty-eight days. 'Flashpack' was invented and patented by the NCB. The patent (1) specifies a range of compositions in the following proportions by weight,

Hydraulic cement	2 - 45%
Flyash	20 - 80%
Inorganic Flocculant	0.05 - 25%
Water	15 - 50%

the components together adding up to 100%. In practice, the composition is strictly maintained to control costs and provide a consistent strength.

2.2 PRACTICE

The 'Flashpack' principle was tested in a surface trial at Parsonage Colliery in Lancashire, U.K. and the management were sufficiently convinced to install the system on a new face in the Haigh Yard Seam. The seam had a previous history of spontaneous combustion and an MPP system was required to reduce the risk of heating brought about by air leakage through the gob.

After some trial and error, the mix design shown in Table 2.1 was adopted. Ferrous sulphate is the inorganic flocculant used and a small quantity of bentonite is added to the flyash slurry to assist in pumping.

Table 2.1 - 'Flashpack' mix design, Parsonage Colliery

	Proportions by Weight	Quantity/m^3
Cement	15.3%	255 kg
Flyash	55.2%	921 kg
Ferrous Sulphate	5.0%	100 kg
Water	22.4%	375 kg
Bentonite	1.1%	18 kg

In early trials, aluminium sulphate was used instead of ferrous sulphate. The latter was substituted to reduce costs. Early pack strength was decreased, but not enough to be a problem. A cement retarder was also used in early trials, sugar in the ratio of 0.4% by weight of cement, but was found not to be needed.

The system in operation at Parsonage Colliery has been described in detail elsewhere (2). The author visited the installation in November 1985 with representatives from CBDC and L.E. Shaw Ltd. of Lantz, Nova Scotia who were awarded a contract by the Department of Supply and Services, Canada to evaluate novel uses of flyash in cement products

(3). A description of the system at the time of the author's visit is given in Appendix B.

2.3 PROPERTIES

2.3.1 Chemical

As indicated earlier, 'Flashpack' is a rapid setting mixture of flyash, cement and water. The chemical composition of the mixture is the basis of the flash setting characteristic, and any attempt to transfer the technology to Nova Scotia must ensure that compatible indigenous components are used. Analyses of the flyash and cement used at Parsonage Colliery and materials available in Nova Scotia are tabulated in Appendix C. Cursory examination of this information and some testing of mixes by CBCRL and the NCB revealed that the constituents available in Nova Scotia would show the flash setting characteristic. Optimum mix designs are being evaluated by Jacques, Whitford and Associates for L.E. Shaw Ltd.

2.3.2 Physical

The strength properties of 'Flashpack' as used at Parsonage Colliery have been evaluated by the National Coal Board. The strength/time properties shown below in Table 2.2 are presented graphically in Figure 2.1, along with the strength/time properties of the 'Astrapack' MPP material currently used at Lingan Colliery.

Table 2.2 - Strength/time characteristics of Parsonage 'Flashpack' material

Time	2 hr	24 hr	7 days	28 days
Strength (MN/m^2)	0.4	1.6	4.4	8.2
(psi)	58	232	638	1189

Immediately apparent is the higher early strength of the 'Astrapack' material compared to 'Flashpack'. The provision of early support at

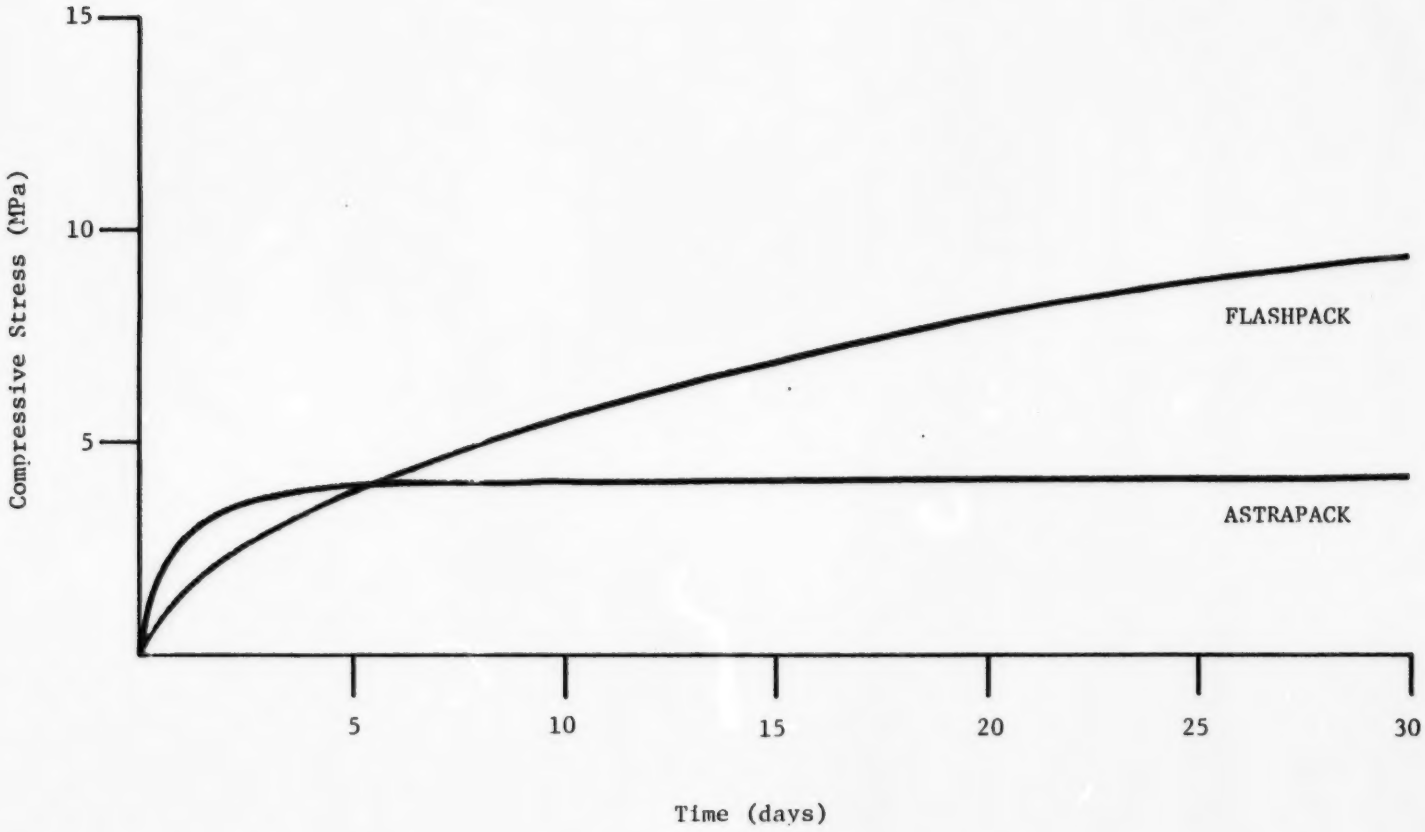

Figure 2.1 - Strength/time properties of 'Flashpack' and 'Astrapack'

the face end is a fundamental requirement of effective gateside packs. Research by the NCB has shown that the level of support offered by 'Flashpack' is acceptable for ground control purposes.

2.4 PRICE

A major attraction of 'Flashpack' is its low cost. Packing costs at Parsonage Colliery can be broken down into three areas: material costs, preparation and placement costs and equipment costs.

2.4.1 Material Costs

The use of flyash and OPC instead of more expensive blended cements make 'Flashpack' a very economic packing method. Flyash and the ferrous sulphate are industrial by-products, and can be bought at low cost in the U.K. Costs of MPP systems in the U.K. based on the most recently available estimates is shown in Table 2.3. 'Aquapack' was used in a short trial at Lingan Colliery in 1982. 'Tekpak' is a similar product to 'Astrapack', marketed by Foseco Ltd. of the U.K. 'Astrapack' is made and marketed by Pozzament U.K. Ltd., who also market 'Aquapack'.

The Parsonage 'Flashpack' shows a distinct cost advantage over the other systems. Using average daily output and face advance figures (supplied by Parsonage Colliery) of 1328 tonnes and 2.54 m respectively, and an average placement of 'Flashpack' of 12.4 m^3 a day, the materials cost per tonne is $0.48. This represents 51% of the total operating cost per tonne.

Table 2.3 - Comparison of monolithic pumped pack systems material costs

System	Cost ($/m^3)	Cost Ratio (Flashpack = 1)
Aquapack*	108.36	2.13
Tekpak*	90.40	1.77
Astrapack**	98.50 (137.00)	1.93 (2.69)
Parsonage Flashpack*	50.94	1.0

Costs exclude packing bag, where used (bags cost approximately $14/m^3)

*Costs shown are ex-works. Delivered costs for 'Astrapack' are shown in parentheses.

*P.S. Mills, Personal Communication, 1985.

**A. Harvey, Personal Communication, 1985.

2.4.2 Preparation and Placement Costs

Comparative preparation and placement costs for all MPP systems are not available, but a detailed breakdown of 'Flashpack' preparation and placement costs at Parsonage Colliery was obtained from the colliery management. Appendix D gives the costs in detail, but in summary, the system absorbs eight manshifts daily costing $789.48. Average earnings per manshift are $98.68. For an average daily output of 1328 tonnes, preparation and placement costs represent $0.59 per tonne. This is 49% of the total operating costs per tonne.

2.4.3 Equipment

Because the implementation of flyash/OPC MPP at Parsonage Colliery was initially a trial only, most of the equipment used was salvaged and refitted or manufactured at the pit. The equipment is described in Appendix B. A cost analysis of the equipment is given in Appendix E. The total equipment cost was $132 K. At the time of the visit, the face had advanced 1400 m. Using an average advance of 2.54 m a day and an average daily saleable output of 1328 tonnes, equipment costs per tonne are $0.18. These costs get less as the face advances further.

2.5 PRECIS

Flyash cement monolithic pump packing at Parsonage Colliery has proven extremely successful. It is accepted by management, and importantly the workmen, as an effective and efficient method of supporting the gateroad and eliminating spontaneous combustion by sealing the long-wall waste.

The wider application of 'Flashpack' within the NCB has been hampered by two factors. Firstly, the fourteen month strike and work-to-rule by colliery unions in the U.K. hindered developments elsewhere. Secondly, because the method used very little of proprietary materials sold by mining suppliers, its advantages have not be disseminated as widely as those of the specially blended rapid setting cement systems produced by, for example, Pozzament and Foseco of the U.K. The limited application of the method should not, therefore, be a reason for rejecting its use in Nova Scotia. ('Astrapack' is not used at all in the U.K. at the time of writing).

With the correct safeguards and design, there is every indication that the 'Flashpack' packing system will prove successful at Lingan Colliery and contribute considerable savings in operating costs.

3. EVALUATION

The following is an evaluation of the applicability of flyash/OPC MPP in Nova Scotia

3.1 MATERIAL SUPPLY

3.1.1 Availability

Materials used in flyash/cement packing are flyash, cement, ferrous sulphate and bentonite. In the U.K., all of these are readily available. Flyash is supplied to Parsonage Colliery from a local station. Ferrous sulphate is a by-product of titanium dioxide manufacture and

is supplied by Imperial Chemical Industries. The U.K. also has indigenous resources of bentonite.

In Nova Scotia, flyash and cement are readily available from sources close to Lingan Colliery. Ferrous sulphate is only obtainable from Quebec, where it is a by-product of the manufacture of nails. Because nail production fluctuates, the availability of continuous supplies of ferrous sulphate is suspect. Bentonite, from Wyoming, is available from the oil service industries in Halifax, Nova Scotia. Preliminary enquiries and examination of the data in Appendix C indicates that all the materials available in Nova Scotia are suitable for use in flyash/cement packing.

3.1.2 Costs

Approximate costs of 'Flashpack' materials from industry sources are shown in Table 3.1 along with costs of materials as supplied to Parsonage Colliery.

Table 3.1 - Cost of 'Flashpack' materials, $/tonne, for Parsonage and Lingan Collieries

Material	Parsonage	Lingan
Flyash	8.20	30.00*
Cement	120.00	162.00*
Ferrous Sulphate	80.00	138.00
Bentonite	148.50	330.00*

*Delivered. All other costs f.o.b. supplier

Ferrous sulphate is currently delivered from Quebec to Lingan Power Station, 1 km from the colliery, at a cost of $1750/20 tonne load. This results in a delivered cost of $225/tonne. The current pump packing system components are delivered from the U.K. (transport costs are $115/tonne). It would appear economic to import both the ferrous sulphate and the bentonite from the U.K., resulting in savings of

$30/tonne and $66.50/tonne respectively. If the Parsonage mix design is used at Lingan Colliery, the costs per cubic metre of pack can be calculated as shown in Table 3.2 below.

Table 3.2 - Projected cost of 'Flashpack' per m^3 at Lingan Colliery

Material	Quantity per m^3 (kg)	Local		Imported	
		cost/tonne ($)	cost/m^3 ($)	cost/tonne ($)	cost/m^3 ($)
Flyash	921	30	27.63	N/A	N/A
Cement	255	162	41.31	N/A	N/A
Ferrous Sulphate	100	225	22.50	195	19.50
Bentonite	18	330	5.94	263.50	4.74
Totals	1294		97.38		93.18

Imported costs per tonne are based on the quoted $115/tonne transportation costs from the U.K. The apparently insignificant difference in cost per cubic metre between mixes based on local and imported materials would result in a saving of $46,000 on a 2500 m long face using a 2.1 m wide by 2.1 m high pack. Referring to Table 2.3 the potential saving attributable to the use of 'Flashpack' in place of 'Astrapack' would be $640K for a 2500 m panel (assuming $93.18/$m^3$ material costs for the 'Flashpack').

It must be emphasised that the costs quoted are approximate; they must be adjusted according to actual material and delivery costs and variations in the mix design required to produce a pack of acceptable strength (described below). Cost reductions in flyash are likely; a reduction in the price of flyash will result in almost dollar-for-dollar reduction of the overall material cost per m^3, and further savings may be gained by using an alternate flocculant. This aspect is currently under review (see below).

3.2 PACK PROPERTIES

The Parsonage 'Flashpack' has proved to be an excellent gateroad support and seal. However, a major difference between Parsonage and Lingan Collieries is the rate of face advance. At Parsonage Colliery the coalface advances at a rate of 12.7 m a week, working two shifts a day. A typical face at Lingan Colliery advances at a rate of 18 - 20 m a week. The difference in face advance rate will obviously affect the strength required of the pack, a higher strength being needed at an earlier stage. If the strength/time properties of the Parsonage 'Flashpack' are accepted as reasonable under face advance conditions of 12.7 m a week, an adjusted strength/time relationship can be proposed for conditions at Lingan Colliery, shown in Table 3.3 below.

Table 3.3 - Required strength/time characteristics of 'Flashpack' adjusted for a face advance of 18 m a week

Time	2 hr	24 hr	7 days	14 days	28 days
Strength (MPa)	0.4	2.4	5.2	6.7	8-11

The 2 hr strength has not been adjusted as it represents the strength obtained prior to advancing the shutter. It is considered unlikely that more than one pack would be required in such a short period.

L.E. Shaw Ltd. have contracted a programme of pack materials testing to Jacques, Whitford and Associates Ltd. of Halifax. The test programme has shown that 'Flashpack' using Nova Scotian materials can have the required strength properties, although the final recommended mix design has not been determined.

3.3 PREPARATION AND PLACEMENT

The 'Flashpack' preparation and placement method employed at Parsonage Colliery was specially designed to make use of equipment available at the pit. Equipment costs specified in Appendix D were therefore

relatively low. The preparation and placement method and the equipment required are obviously related.

The 'home-made' approach used at Parsonage Colliery could also be adopted at Lingan Colliery, but additional sophistication can be introduced to ease transportation effort. The system options are illustrated in Figure 3.1 to 3.4 and are described briefly below. One option which has not been considered is to bag the flyash and transport it underground to be mixed at the gate end or gate deep junction. Excessive materials handling and the extra cost of bagging the flyash are the basis for its exclusion, although initial underground trials could use the method.

3.3.1 Option One

Option one is based on the Parsonage 'home-made' approach. The flyash slurry is mixed on the surface and transported underground in mine cars. From the gate deep junction it is pumped from the mine cars to a gate end storage tank equipped with an agitator. The cement pumping station is identical to the Parsonage installation.

3.3.2 Option Two

For option two the mine cars are replaced by pumping the flyash slurry from the surface. The pipeline must be insulated for at least part of the way down the deep to prevent freezing. An additional flyash mixer is required for continuous packing. Once again, the cement pumping station is identical to the Parsonage system.

3.3.3 Option Three

In option three a pneumatic cement handling system is introduced. Pneumatic handling of packing materials is widely practised in Germany, but has only recently been introduced in the U.K., where sophisticated telemetry systems are used to control cement flow and reduce manpower requirements (4). The Coventry Colliery system in the

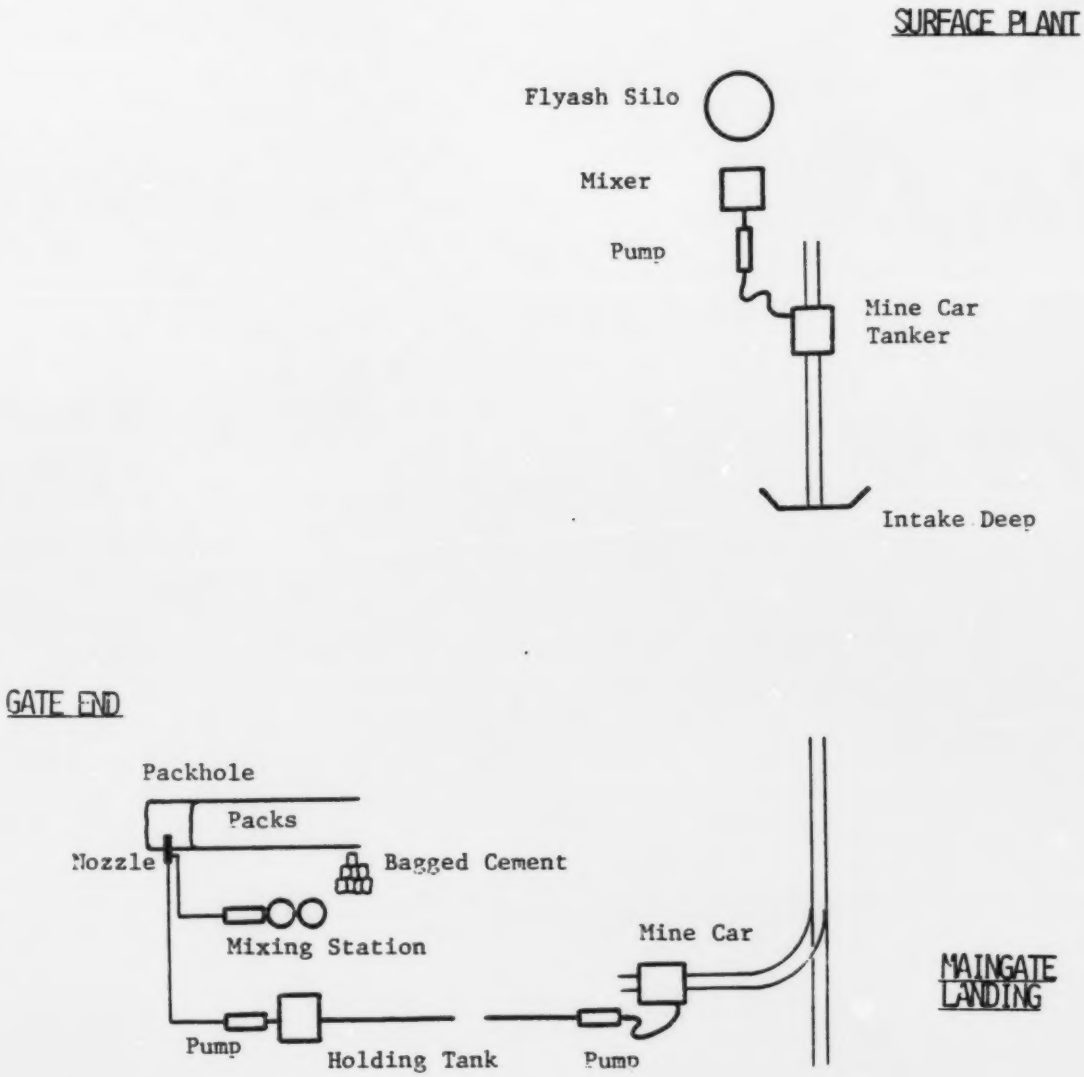

Figure 3.1 - 'Flashpack' at Lingan Colliery
placement option one

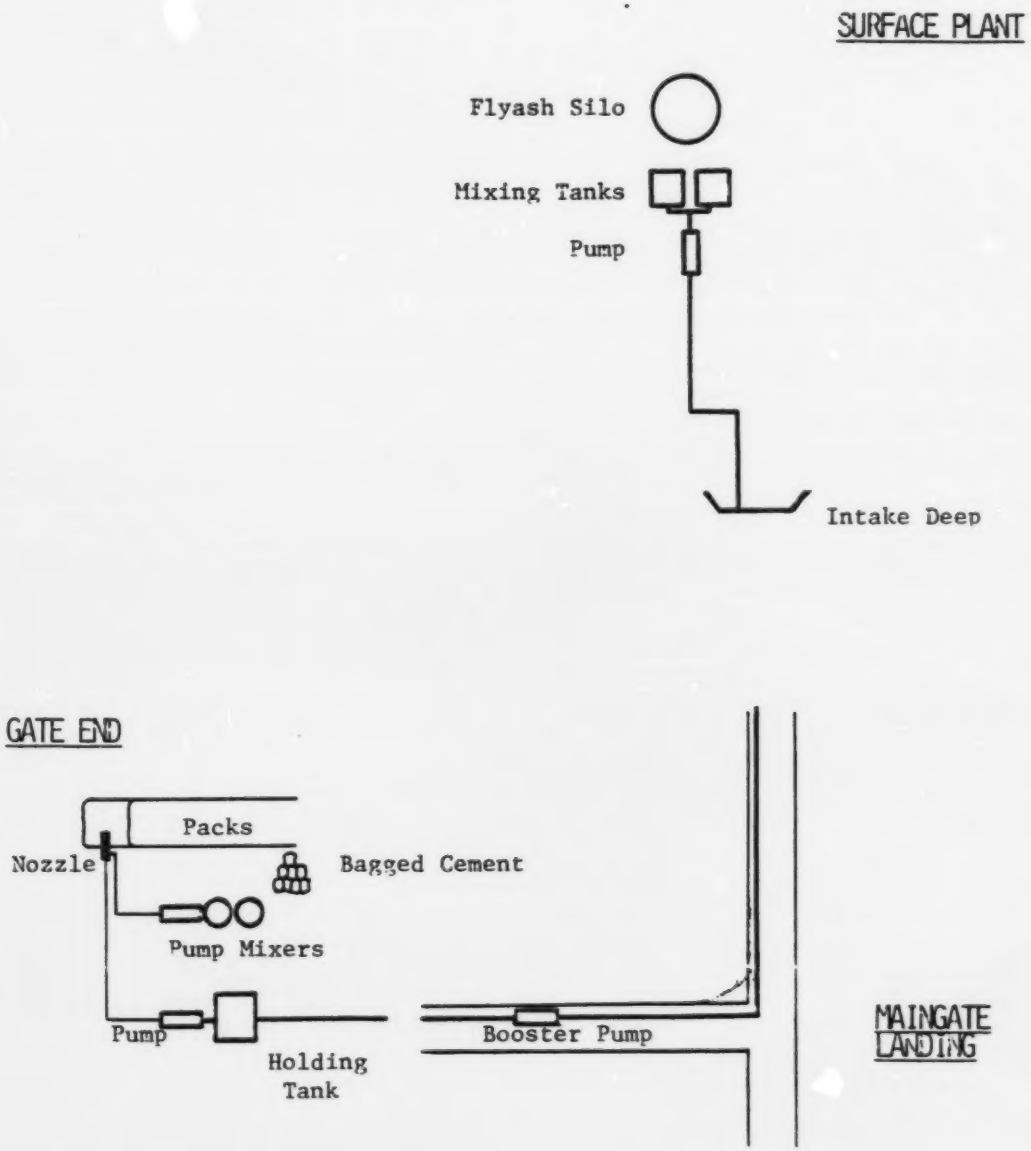

Figure 3.2 - 'Flashpack' at Lingan Colliery placement option two

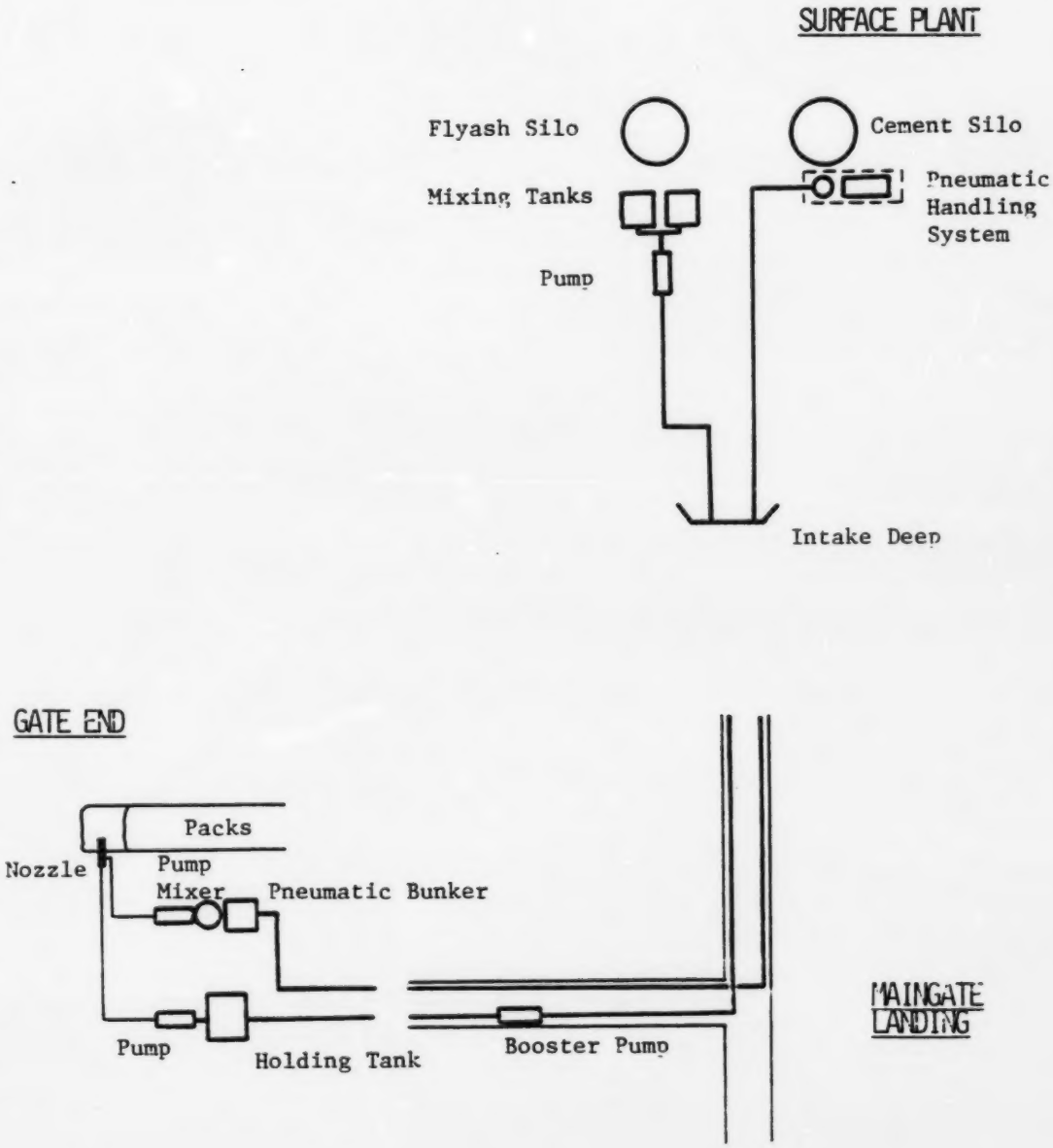

Figure 3.3 - 'Flashpack' at Lingan Colliery
placement option three

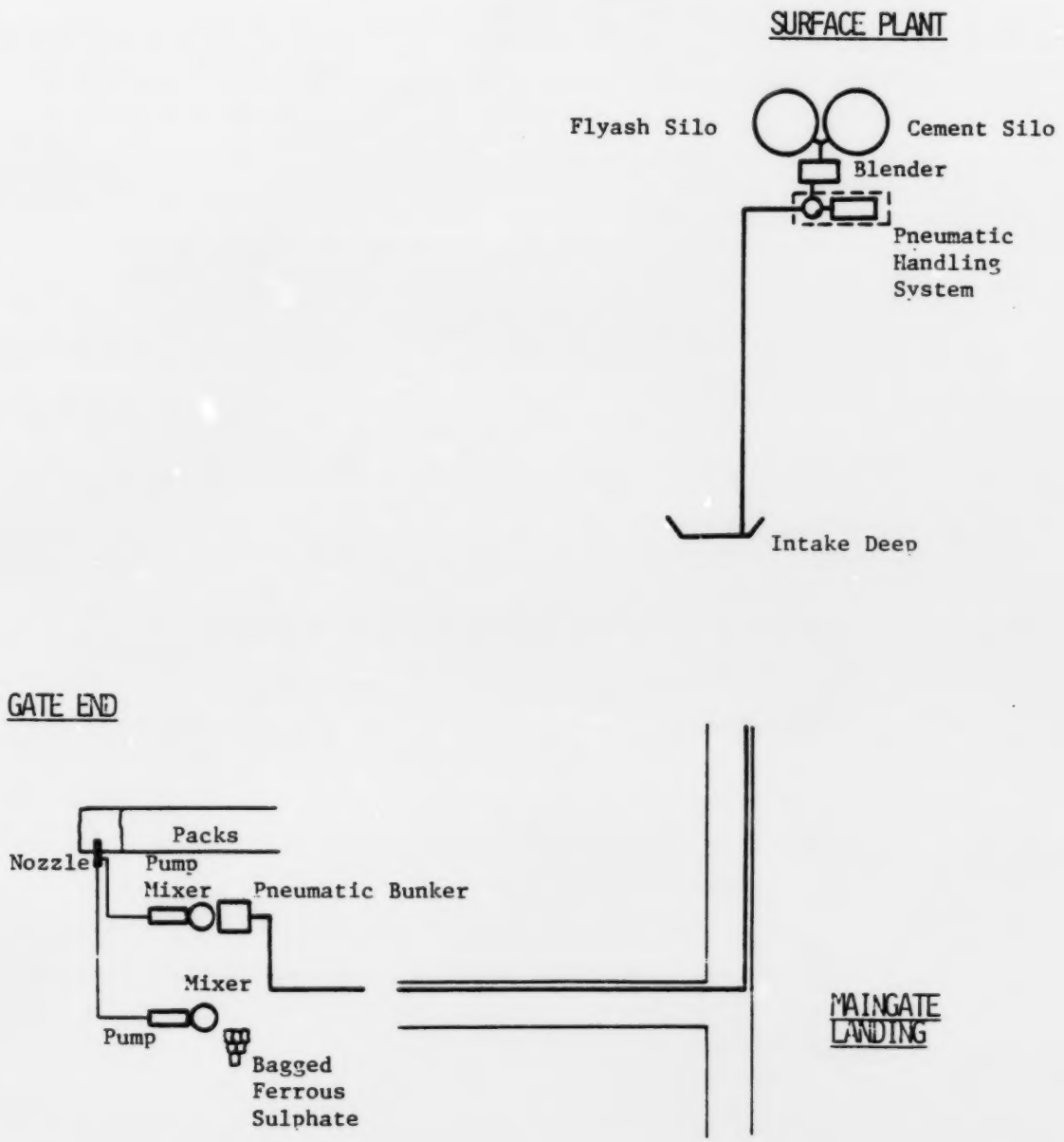

Figure 3.4 - 'Flashpack' at Lingan Colliery placement option four

U.K. was visited by the author. Except for some redesign work due to under-specification of the initial equipment, the system works exceptionally well and provides significant benefits.

3.3.4 Option Four

Option four makes use of a pneumatic handling system to deliver a blend of flyash and cement to a pneumatic bunker at the face end. The blend is produced on the surface from individual cement and flyash silos. At the face end, the blended powder is mixed and pumped to the packhole, where it meets a solution of ferrous sulphate, admitted in the correct proportions to ensure a flash set. In this system only 700 kg of material must be brought into the face end area.

3.4 EQUIPMENT

No more than a general evaluation of the equipment required for the various options can be conducted without detailed costs.

Option one is the least costly, but the pipelining of the flyash slurry as shown in option two significantly reduces transportation difficulties.

Pneumatic handling systems proposed in options three and four are extremely expensive initially, but offer substantial reductions in manpower costs and material losses. The automation of such systems is a proven concept and may eventually lead to fully automated packing. Unless applied to several districts, pneumatic handling systems at Lingan Colliery may take four to six years to pay back.

3.5 EVALUATION SUMMARY

This evaluation indicates that packing materials of suitable quality are available at an attractive cost in Nova Scotia. Pack properties can be designed to provide an appropriate level of support for Lingan

conditions. Mix designs are currently being investigated to select materials and material quantities required for optimum pack properties.

Preparation and placement options must be evaluated on the basis of equipment costs, manpower requirements and the number of packing installation anticipated. This can best be done by CBDC staff and has not been attempted here. A more rigourous evaluation of these options is one of the recommendations stated at the end of the report.

4. HEALTH AND SAFETY

Health and safety aspects of 'Flashpack' use (outside of normal requirements of underground coal mining) concentrate on the nature of the material used.

Any cement material poses a health hazard if used recklessly. Alkali is released during hydration and may cause chemical burns if allowed to come into contact with human tissue; mucous membranes and eyes are particularly susceptible, as is sweaty skin. The hazard is magnified by the enclosed conditions and flying dust associated with the mining environment. Ordinary portland cement poses a lower hazard than the faster reacting specially blended cements currently manufactured for packs, but conventional safeguards should be employed during handling.

Ferrous and aluminum sulphates are conventionally used as food additives, but impurities in the form in which they are used in packing may cause irritation of the eyes and mucous membranes. Handling safeguards used with cement are adequate precautions. Available health and safety data for 'Flashpack' constituents is presented in Appendix E. One other factor to consider is the possibility of workers developing an allergic reaction to the substances. In this instance, reallocation to other tasks is recommended.

5. CONCLUSIONS

Flyash/cement packing is very successful at Parsonage Colliery in the U.K. It provides an excellent ventilation seal and gives good gateroad support. It is accepted by management and workers as an efficient and effective packing method.

The study described above has shown that the material could be used in CBDC collieries resulting in a substantial saving over current monolithic packing methods, whilst maintaining an effective ventilation seal. The higher strength of 'Flashpack' and its higher solids ratio will improve support in the gateroads, resulting in larger cross-sectional areas and more efficient transportation and ventilation.

6. RECOMMENDATIONS

The following course of action, comprising evaluation, trial and implementation phases, is recommended for the introduction of flyash/cement packing at Lingan Colliery.

6.1 EVALUATION

A thorough evaluation or the practicability and, more importantly, the cost should be carried out by a competent engineer. The following aspects should be included:

1. Optimum mix design
2. Projected use (tonnes/year)
3. Preparation and Placement
   Options
   Cost (manpower, materials)
   Payback
4. Projected Benefits

6.2 TRIAL

Once the mix design has been finalised, existing equipment should be used at a suitable surface or underground location to demonstrate the packing method to colliery management, supervisors and workmen. This should be supervised by the responsible engineer.

6.3 IMPLEMENTATION

Based on the results of the evaluation, the selected method should be introduced at the start of a longwall panel. The effect of the method on ventilation and strata control should be evaluated in a similar manner to the investigations carried out on the 'Astrapack' system in the 9E District.

7. ACKNOWLEDGEMENTS

The assistance of British Mining Consultants Limited, the National Coal Board and Colcrete U.K. Ltd. in arranging the technical visit at short notice is acknowledged.

Management and workmen at Parsonage and Coventry Collieries generously gave their time explaining various aspects of the system observed.

The author acknowledges the assistance of L.E. Shaw Ltd. of Lantz, Nova Scotia in making the visit and compiling this report.

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3. "Development of engineering data on Nova Scotia flyash"; DSS File #14SQ.23440-4-9308. Contract awarded to L.E. Shaw Ltd. of Lantz, N.S. on behalf of CANMET.

4. Sampson, J.D. "Introduction of bulk handling systems for packing materials in mining"; Paper presented to the Institute of Min. Elec. and Min. Mech. Engineers, South Midland Branch, U.K.; 11th October 1984.

APPENDIX A

Visit Itinerary and Personnel

A1 VISIT ITINERARY AND PERSONNEL

A1.1 ITINERARY

Monday, November 11	a.m.	-	Arrive at Leigh, U.K.
	p.m.	-	Meeting with Parsonage Colliery Undermanager, Mr. Alan Boyne to discuss visit.
Tuesday, November 12	a.m.	-	Underground visiting 'Flashpack' installation.
	p.m.	-	Meeting with Colliery Management and Dr. P.S. Mills, NCB Technical Services, Bretby.
Wednesday, November 13	a.m.	-	Underground visiting installation.
	p.m.	-	Tour of surface plant.
Thursday, November 14	a.m.	-	Underground visiting installation.
	p.m.	-	Travel to Coventry.
Friday, November 15	a.m.	-	Visit Coventry Colliery pneumatic handling system, surface and underground.

A1.2 PERSONNEL

Mr. A. Harvey, Mining Engineer, CBDC
Mr. G. Ellerbrok, Mining Engineer, CBDC

Mr. S. Acker, President, L.E. Shaw Ltd., Lantz, N.S.

Dr. P. Cain, Research Scientist, CBCRL

APPENDIX B

Flyash/Cement Packing at Parsonage Colliery

B1 FLYASH/CEMENT PACKING AT PARSONAGE COLLIERY

The flyash/cement packing system consists of two separate slurry circuits, described below. The system is shown diagrammatically in Figure B.1.

B1.1 FLYASH SLURRY SYSTEM

The flyash, wetted to reduce airborne dust, is delivered to the colliery yard in 20 tonne trucks. It is tipped into and stored in a 35 tonne surface bunker. The bunker feeds an AFC which in turn feeds a belt conveyor. The belt conveyor loads the flyash directly into a 730 L (160 gal) Colcrete SD24 colloidal mixer.

A batch of flyash slurry is prepared as follows. The mixer is filled to a predetermined level and bentonite and ferrous sulphate are then added in the required amounts. The mixer is then topped up to the 730 L level by adding flyash. The mixed slurry is pumped into converted mine cars and conveyed underground to a pit bottom pumping station. From there it is pumped to an inbye holding tank (situated 200 - 300 m from the face) along a (76 mm) 3" Victaulic pipe by a CLM 411 monopump. A similar booster pump is located approximately 1250 m from pit bottom in case it is required (Figure B.1). The inbye tank is fitted with compressed air driven paddles to maintain the flyash in suspension.

B1.2 CEMENT SLURRY SYSTEM

Adjacent to the flyash holding tank is the cement slurry station. This consists of:

a) two GM30 Mindev paddle mixers (256 L, 56 gal)
b) a Colcrete colloidal mixer
c) a single acting Mindev 95 mm pump
d) a 30 kW (40 hp) electrohydraulic power pack

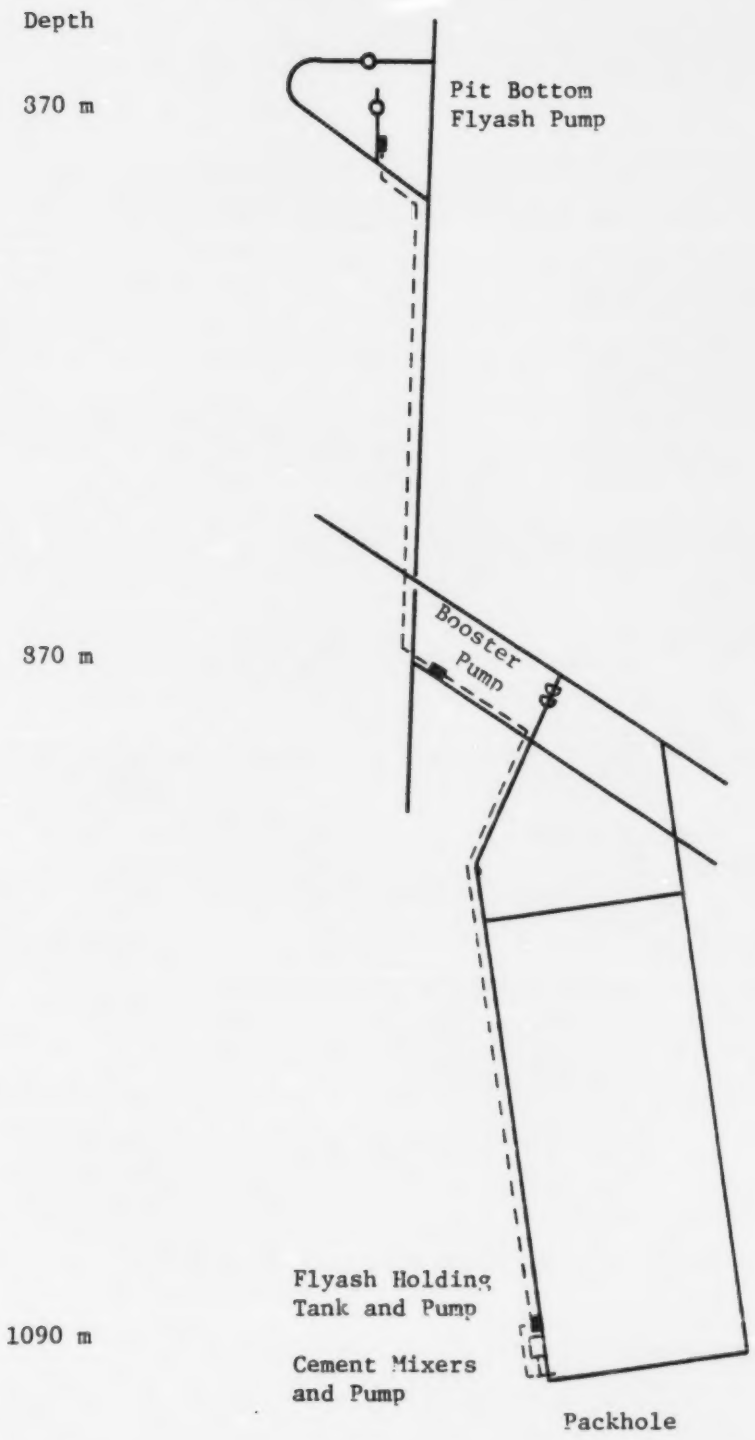

Figure B.1 - Schematic layout of flyash/cement packing

To prepare the cement slurry twenty gallons of water is fed into the colloidal mixer and six 25 kg bags of OPC are added. From the mixer the slurry is fed to the GM30 mixing tanks.

B1.3 PACKING PROCEDURE

The packhole is defined by a sheet steel curtain and very little preparation is required. The cement is pumped from the GM30 tanks at a rate of 55 L/min (12 gpm) where it mixes with the flyash, pumped at 182 L/min (40 gpm) at CLM 411 monopump in a special gun. Both grouts are delivered along 32 mm (1 1/4") armoured flexible hose.

The mixture gels instantly. A packing rate of up to 22 m^3/hour can be achieved, but the limited size of the flyash holding tank requires an intermittent packing process to allow refilling.

APPENDIX C

Comparison of Component Chemistry

Table C.1 - Comparison of Parsonage flyash and Nova Scotia flyash composition

Constituent	Parsonage* (%)	Nova Scotia** (%)
Silica	51.8	43.1
Alumina	30.4	23.45
Ferric Oxide	9.5	22.22
Calcium Oxide	1.6	0.46
Magnesia	1.4	0.9
Sodium Oxide	1.6	0.51
Potassium Oxide	3.8	2.60
Sulphate	0.67	0.85
Loss on Ignition (LOI)	3.3	1.07
Specific Surface	350	N/A
+45 micron fraction	20	N/A

* P.S. Mills, Personal Comunication.

** Sampled 3/9/83 Analysed by Nova Scotia Research Foundation Corporation for Nova Scotia Power Corporation.

Table C.2 - Comparison of Parsonage cement and Nova Scotia cement composition

Constituent	Parsonage* (%)	Nova Scotia** (%)
Silica	20.1	20.06
Alumina	5.5	5.47
Ferric Oxide	2.7	2.14
Calcium Oxide	64.7	62.95
Magnesia	1.3	1.3
Sodium Oxide	0.23	1.4
Potassium Oxide	0.73	1.31
Sulphate	2.8	3.63
Loss of Ignition (LOI)	1.0	2.75
Free Lime	1.7	N/A

* P.S. Mills, Personal Communication.

** Canada Cement type 10 (OPC) ex. Brookfield, N.S. February 1984.

APPENDIX D

'Flashpack' Preparation and Placement Costs at Parsonage Colliery

D1 FLASHPACK PREPARATION AND PLACEMENT COSTS AT PARSONAGE COLLIERY

The packing system absorbs eight man shifts per day. Detailed costs are shown below.

D1.1 SURFACE

1 man per coaling shift = 2 man shifts per day

Average EMS*	$ 53.52
Average wages charged per shift	$ 30.40
Average cost per shift	$ 83.92
Average cost per day	$167.84

*Earnings per man shift

D1.2 PIT BOTTOM PUMPING STATION

1 man per coaling shift = 2 man shifts per day

Average EMS	$ 63.14
Average wages charged per shift	$ 30.40
Average cost per shift	$ 93.54
Average cost per day	$187.08

D1.3 Y1 INTAKE PUMPING STATION

1 man per coaling shift = 2 man shifts per day

Average EMS	$ 78.24
Average wages charged per shift	$ 30.40
Average cost per shift	$108.64
Average cost per day	$217.28

D1.4 PACKHOLE

1 man per coaling shift = 2 man shifts per day

Costs are the same as the Y1 pumping station, i.e. $217.28/day.

D1.5 TOTAL COSTS

Surface	$167.84 per day
Pit Bottom Station	$187.08 per day
Y1 Station	$217.28 per day
Packhole	$217.28 per day
Total Cost	$789.48 per day

Using an average daily saleable output of 1328 tonnes per day, the average manpower costs are $0.59/tonne.

APPENDIX E

'Flashpack' Equipment Costs at Parsonage Colliery

E1 FLASHPACK EQUIPMENT COSTS AT PARSONAGE COLLIERY

Much of the equipment required was fabricated at the pit from scrap or salvaged materials. Costs for each location are detailed below.

E1.1 SURFACE

35 tonnes capacity flyash bunker (pit labour costs only) (made at the pit from disused boiler house bunkers).	= $ 1000 (est.)
500 mm armoured conveyor with 48 kW (65 hp) drive.	= $36000 (est.)
Huwood T.B. 40 - 36" belt conveyor.	= $30000 (est.)
Colcrete S.D.24 colloidal mixer (730 L, 160 gal) capacity.	= $ 6840
Six 2275 L (500 gal) capacity transporter tanks (fabricated at the pit) at $500 each.	= $ 3000 (est.)

E1.2 PIT BOTTOM PUMPING STATION

CLM 411 monopump (30 kW, 40 hp drive).	= $ 9224
Two thousand 76 mm (3") diameter Victaulic pipes at $30 per 6 m length plus $13 per housing.	= $14000 (appx)

E1.3 Y1 INTAKE PUMPING STATION

1820 L (400 gal) capacity flyash mixing tank with paddle mixer and Eimco compressed air motor (assembled at pit).	= $ 500 (est.)
CLM 411 monopump.	= $ 9224
Mindev 30 kW (40 hp) power pack.	= $13096
Two Mindev G.M. 30 agitation tanks at $2660.	= $ 5320
Colcrete S.D.4 colloidal cement mixer.	= $ 6842
Mindev ramp pump (95 mm).	= $ 9046
Two 32 mm (1.25") diameter flexible armoured hose, 200 m long at $900 per 90 m length.	= $ 4000

E1.4 PACKHOLE

Sheet steel curtains.	= $ 100(est.)
Two mixer guns (made at pit).	= $ 100(est.)
Trailing and control cables will be required at an approximate cost of $4000.	= $ 4000
The total cost of equipment for the installation.	$132000 appx

The labour costs of installation have not been identified.

Using a face advance of 2000 m, a daily advance of 2.54 m and an average daily output of 1328 tonnes per day, the equipment costs per tonne can be calculated as $0.12. This will decrease if the face advances past the 2000 m mark.

APPENDIX F

Available Safety and Health Data for 'Flashpack' Constituents

F1 AVAILABLE SAFETY AND HEALTH DATA FOR FLASHPACK CONSTITUENTS

F1.1 ALUMINIUM AND FERROUS SULPHATE

The safety and health data for aluminium and ferrous sulphate from information supplied by the NCB Western Area Scientific Department are given below:

Threshold Limit Values 1980

	Airborne Particles T.L.V. T.W.A.	Particles mg/m^3 STEL
Aluminium Sulphate Salts	2	-
Iron, Soluble Salts (as Fe)	1	2

Aluminium Sulphate

Aluminium sulphate hydrolyses readily to form some sulphuric acid which acts as a tissue irritant, particularly to the lungs. It is used as a general food additive for neutralisation and buffering purposes (control of pH). In solution aluminium sulphate has a pH = 3 to 3.5.

Ferrous Sulphate

Ferrous sulphate does not hydrolyse in a similar manner, but in air, it oxidises to ferric sulphate, which hydrolyses in the same way as aluminium sulphate, a ferric sulphate solution having a pH = 2.5 to 3 (compare with ferruginous mine water). Ferrous sulphate is used as a nutrient and/or dietary supplement food additive as well as a trace mineral added to animal food; it is a substance migrating to foods from packaging materials.

In general terms, although ferrous sulphate is a mild reducing agent and in oxidised form, as ferric sulphate, it is potentially more acidic that aluminium sulphate; in practice it is not likely to present a significantly greater hazard. Contamination of the skin, eyes and mucous membrane. Inhalation and ingestion of both aluminium and ferrous sulphate powders is likely to have an irritant, although not generally permanent, effect and should therefore be avoided.

In context the use of either compound in conjunction with the cement used for packing, the recommended protective clothing, goggles, dust masks, gloves, etc. should provide adequate protection.

F1.2 CEMENT

Handling procedures can be summarised by the following generalised terms:

F1.2.1 PRECAUTIONS

- avoid creating dust
- avoid inhalation of dust
- avoid skin and eye contact
- wear full protective clothing, including goggles, dust mask, suitable gloves and waterproof leggings particularly during prolonged or frequent use
- provide eye washing facilities

F1.2.2 FIRST AID

Eye - Flush copiously for at least 15 minutes. If irritation persists seek medical advice.

Skin - Flush copiously with water. If irritation persists seek medical advice.

Inhalation - Remove to fresh air. If discomfort persists seek medical advice.

Ingestion - Give plenty to drink. If massive amount ingested or if discomfort persists, seek medical advice.